appeared ion 23rd Feb 2005

Silicon in the fast track

There is something of a sensation in science circles since advances towards creating a silicon laser were announced last week, says S.Ananthanarayanan.

This possibility, in a material that is at the heart of all electronics, promises a way around the speed barrier that may soon limit how far silicon devices can go. If silicon atoms could emit laser photons, then components in a silicon microcircuit could communicate at the speed of light!

Silicon and electronics

Silicon is special among atoms because of its atomic structure. All atoms consist of a positively charged centre, surrounded by clouds of negatively charged electrons, which just balance the charge at the center. The electrons are distributed in shells and the last shell must have not more than 8 electrons. If there is one more, it starts a new shell with one electron. There is also a rule that the stable condition is for atoms to have 2 or 8 electrons in the outer shell and atoms all ‘borrow and lend’ to get into this blessed state. It is this trading activity that leads to chemical bonding.

In silicon, the outer shell has 4 electrons – which is half way between ‘8 and 8’. It can then get into a stable form just in a lattice of silicon atoms, with each atom sharing its 4 outer electrons with 4 of its neighbours.

If such a silicon crystal is ‘doped’ with an atom that has 5 or 3 outer electrons, then that atom also joins the regular pattern, but with an unmatched ‘free’ electron or a ‘free’ electron ‘hole’. It is the mobility of this electron or hole that accounts for all the current and voltage manipulating marvels of diodes, transistors and integrated circuits.

Limits to the marvel

In ‘integrated circuits’, slivers of silicon are cleaved from cylindrical crystals and used as the base for scores of diodes and transistors all on one sliver. Depositing specks of ‘dopants’ creates the components and depositing hair-thin gold connectors on to the same slivers connects the components. The technology has got sophisticated and dime-sized ‘chips’ now carry thousands of electronic components.

But while the components get smaller and crowded, how fast the devices can actually work is limited by the limits to the size of physical connectors. The speed of electricity through metals is also too sluggish for the lightning speeds that electronic devices need. And then, there is the heat generated by the electric currents.

Lasers and communications

Lasers are groups of atoms that emit light all together, or in unison. A beam of laser light which is like an army rching in step, rather than a jostling crowd, hence stays powerful and on course. But getting atoms to emit light like this has been possible only with atoms with the right properties. One of the properties is that the atoms should have an energy state to which they can be ‘pumped up’ and ‘parked’. Then, a photon of light of the right frequency can set off several ‘parked’ atoms to emit light together, producing a laser burst. A continuous beam of such light can be coded and used to convey huge flows of information.

Getting the silicon atom to emit laser light could then enable communication within silicon devices and also eliminate the interface that now needs to bridge the separation between the devices and communication channels.

The silicon laser

What has now been achieved is a silicon laser that works in the infra-red region. It is not like a conventional laser that uses ‘metastable’ atomic states, but makes use of ‘vibration’ states of the crystal structure instead. Photons from an ‘excitation’ laser pass energy to the lattice when they bounce off silicon atoms. The lattice then ‘de-excites’ in phase, to emit laser light at the vibration frequencies of the lattice. The losing of energy by photons to vibration modes of atoms and molecules is known as the Raman effect and using the property to make lasers is known as ‘stimulated Raman scattering’.

Scientists at Intel Corporation built on work of scientists at the University of California at Los Angeles to get continuous laser light along a channel in silicon crystals.